Maintaining Water Supplies to a Remote Island Population when Source Water Becomes Contaminated

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Report Documentation Page

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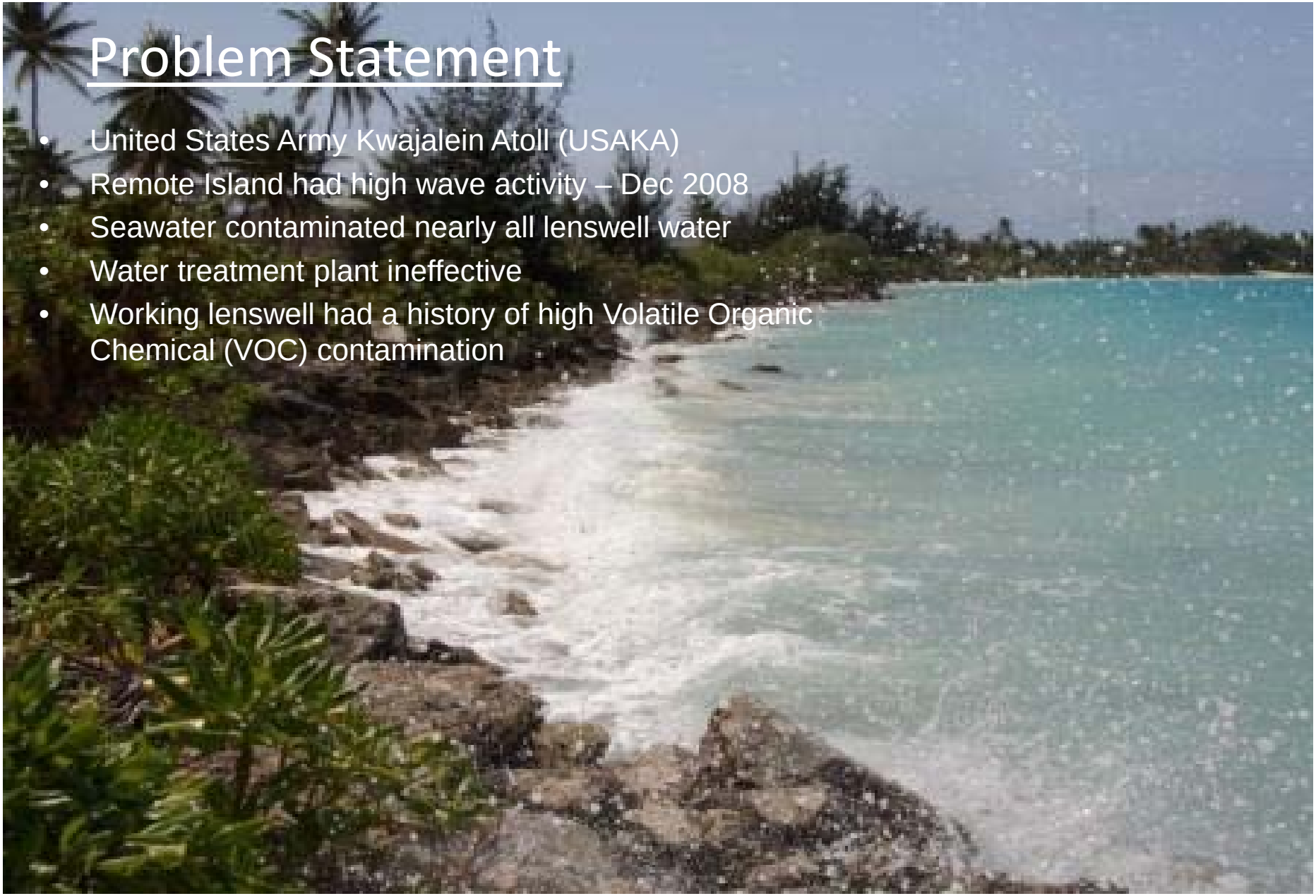
Satellite picture of the Atafu atoll in Tokelau in the Pacific Ocean (reference 1)

Problem Statement

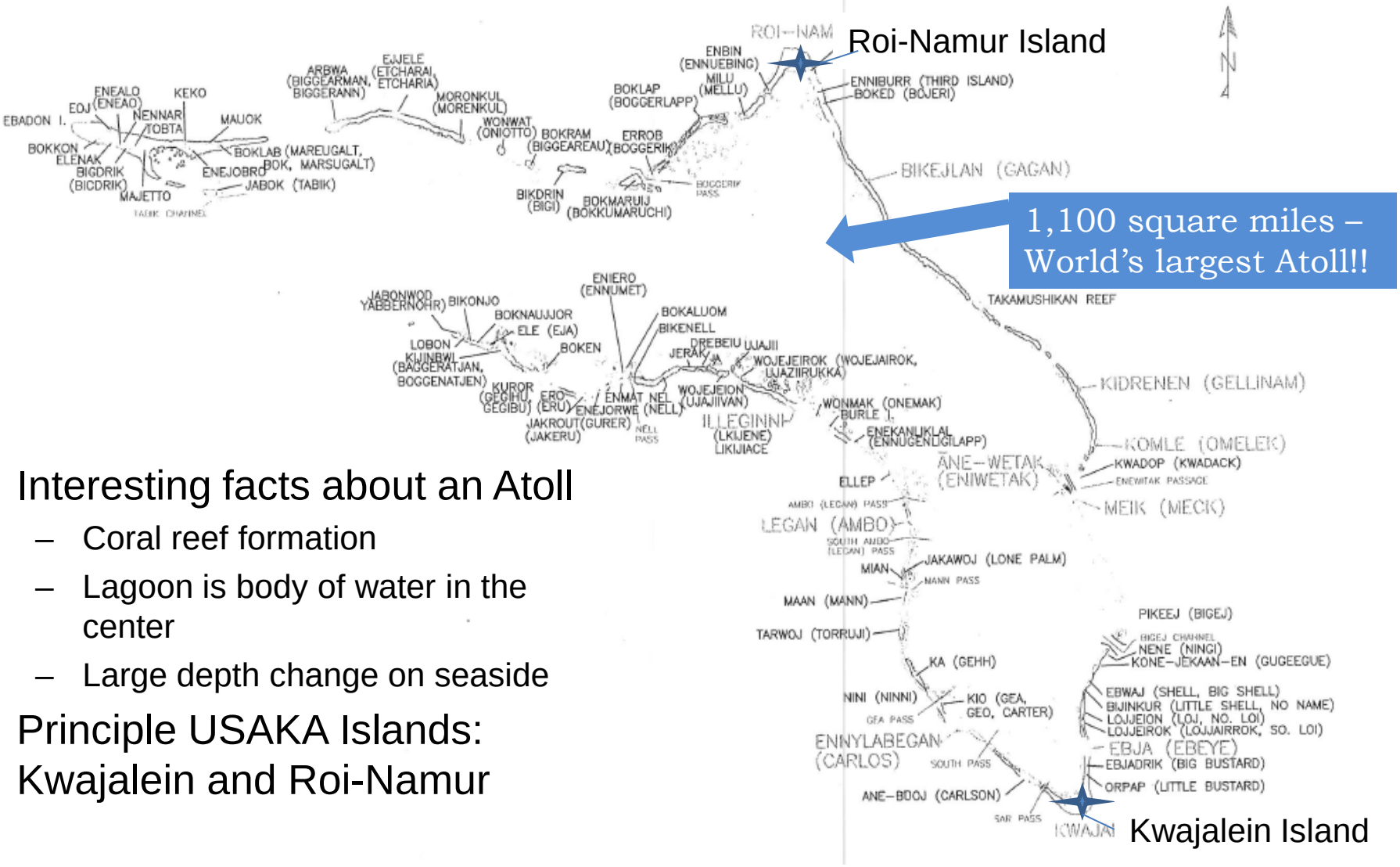
- United States Army Kwajalein Atoll (USAKA)
- Remote Island had high wave activity – Dec 2008
- Seawater contaminated nearly all lenswell water
- Water treatment plant ineffective
- Working lenswell had a history of high Volatile Organic Chemical (VOC) contamination



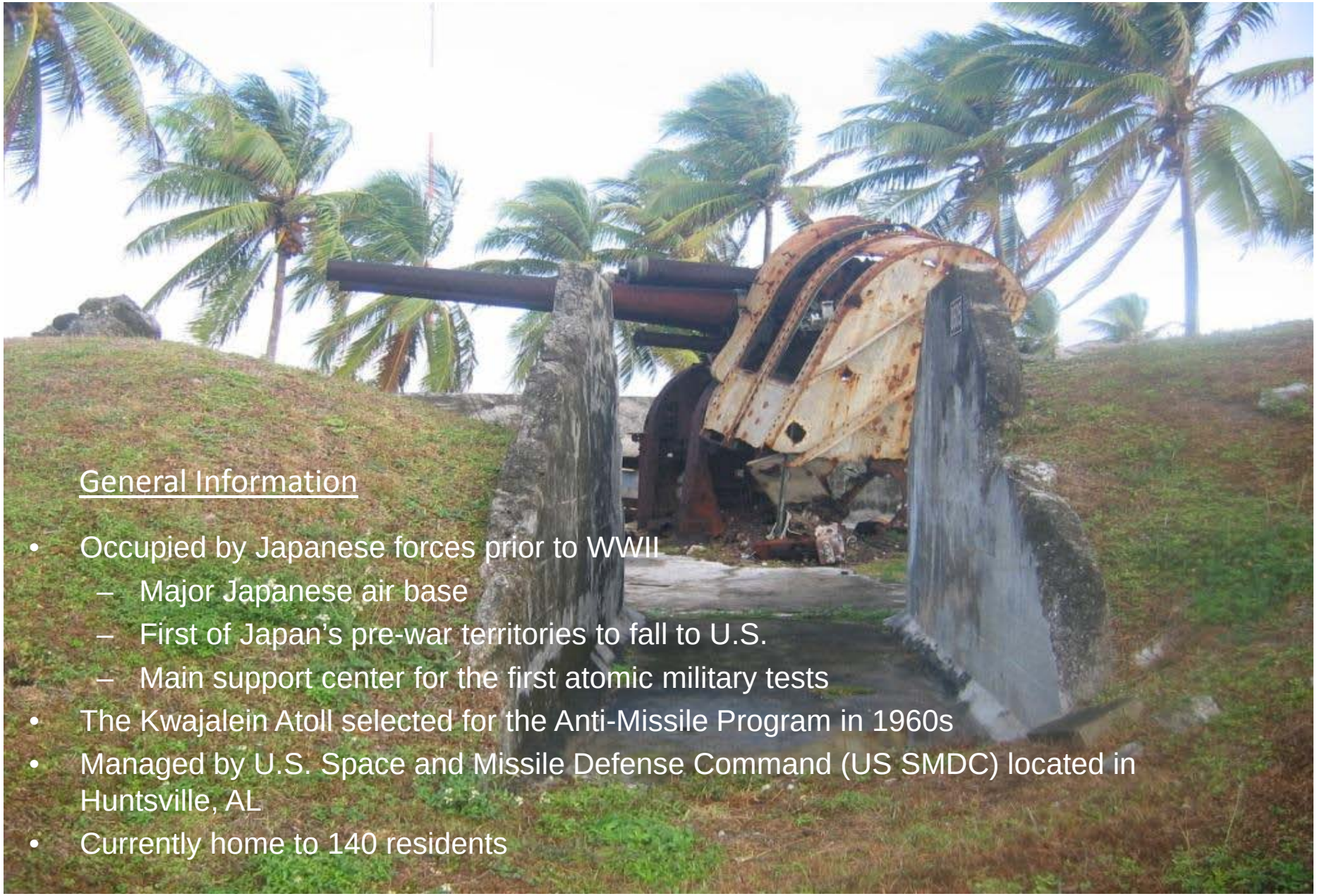
Where is the United States Army Kwajalein Atoll?

Location	Time	Day
Kwajalein	7:30 AM	Tuesday
Honolulu	9:30 AM	Monday
Los Angeles	11:30 AM	Monday
Denver	12:30 PM	Monday
New Orleans	1:30 PM	Monday
Baltimore	2:30 PM	Monday

What is an Atoll?



- Interesting facts about an Atoll
  - Coral reef formation
  - Lagoon is body of water in the center
  - Large depth change on seaside
- Principle USAKA Islands: Kwajalein and Roi-Namur



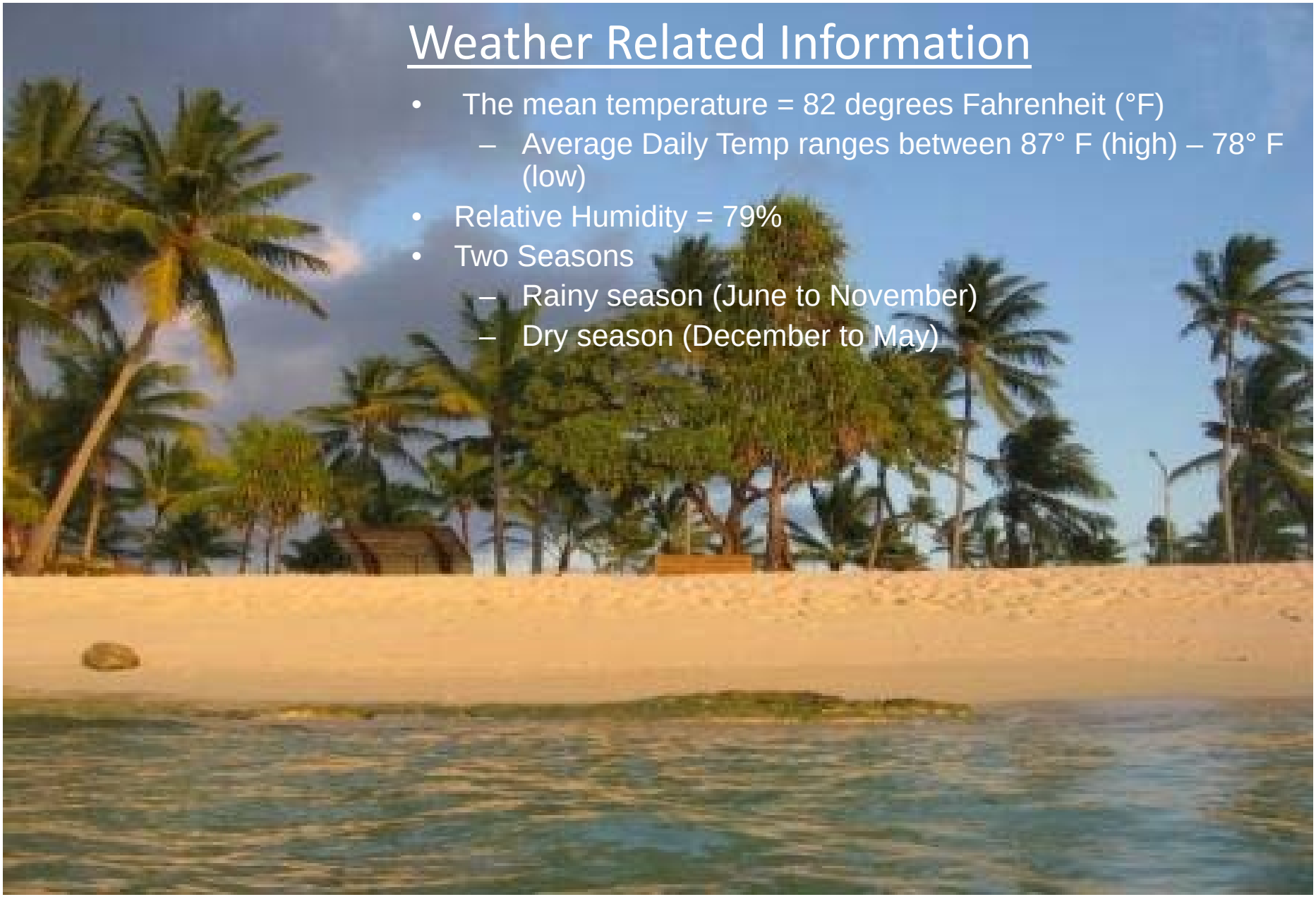
General Information

- Occupied by Japanese forces prior to WWII
  - Major Japanese air base
  - First of Japan's pre-war territories to fall to U.S.
  - Main support center for the first atomic military tests
- The Kwajalein Atoll selected for the Anti-Missile Program in 1960s
- Managed by U.S. Space and Missile Defense Command (US SMDC) located in Huntsville, AL
- Currently home to 140 residents

Roi-Namur From The Air

Weather Related Information

- The mean temperature = 82 degrees Fahrenheit (°F)
  - Average Daily Temp ranges between 87° F (high) – 78° F (low)
- Relative Humidity = 79%
- Two Seasons
  - Rainy season (June to November)
  - Dry season (December to May)



Island Survival

Primary water source – Rain Water

Monthly Rainfall (inches) - Data From 2002 - 2006 (reference 2)

MONTH	EXTREME MIN	EXTREME MAX	AVERAGE
January	0.48	15.66	4.32
February	0.04	10.21	3.02
March	0.16	24.33	4.72
April	0.20	20.09	6.78
May	0.53	26.86	9.02
June	3.56	19.61	9.15
July	3.53	22.29	10.05
August	5.38	23.61	10.50
September	3.77	21.16	11.08
October	5.04	20.05	11.99
November	3.51	19.51	10.97
December	1.90	30.38	8.50

- Rain water collected via water catchments (23 acres) (reference 3)
- Daily Water Demand on Roi-Namur is 35,000 Gallons per Day (GPD) (reference 4)
- What amount of rainfall is required to meet Roi-Namur water demands?

Where Does All The Water Go?

- Evaporation rate difficult to assess but it is a substantial loss

- Carrier equation - developed for unoccupied pools (reference 5)

$$E = \frac{(95 + 0.425 * u) * A * \Delta p}{i} \rightarrow 0.021 \frac{ft}{day}$$

Where:

E = rate of evaporation (lbs / hr)

u = velocity of air parallel to water (ft/min) (low values or 0 are normally used)

A = Surface area of pool (ft^2)

p = partial pressure of water in air (inches of Hg)

Δp = p (at water-surface temperature) – p (at room temperature)

i = latent heat of vaporization (BTU / lb)

- Regional evaporation rate data (reference 6 and 7)
  - -Brisbane Australia = 0.024 ft/day
  - -Hagatna Guam = 0.020 ft/day

*•Required monthly rainfall - **8 inches** per month to meet drinking water demand before using lenswells*

•Therefore, rainfall during the dry season typically is not enough to meet demand

•Where does Roi-Namur get its make-up water?

Lenswell Reliance

- What are lenswells?
  - Fresh water less dense than salt water
  - Replenished by rain water (recharge)
  - Lenswells are shallow and spread over a long length of the aquifer
  - Estimated 226 million gallons (Mgal) of potable water (reference 3)

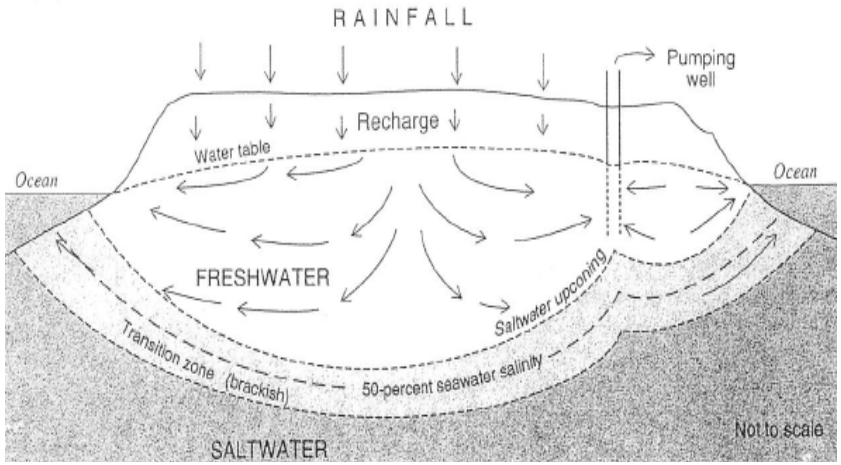


Diagram taken from Reference 3

A Picture Is Worth…

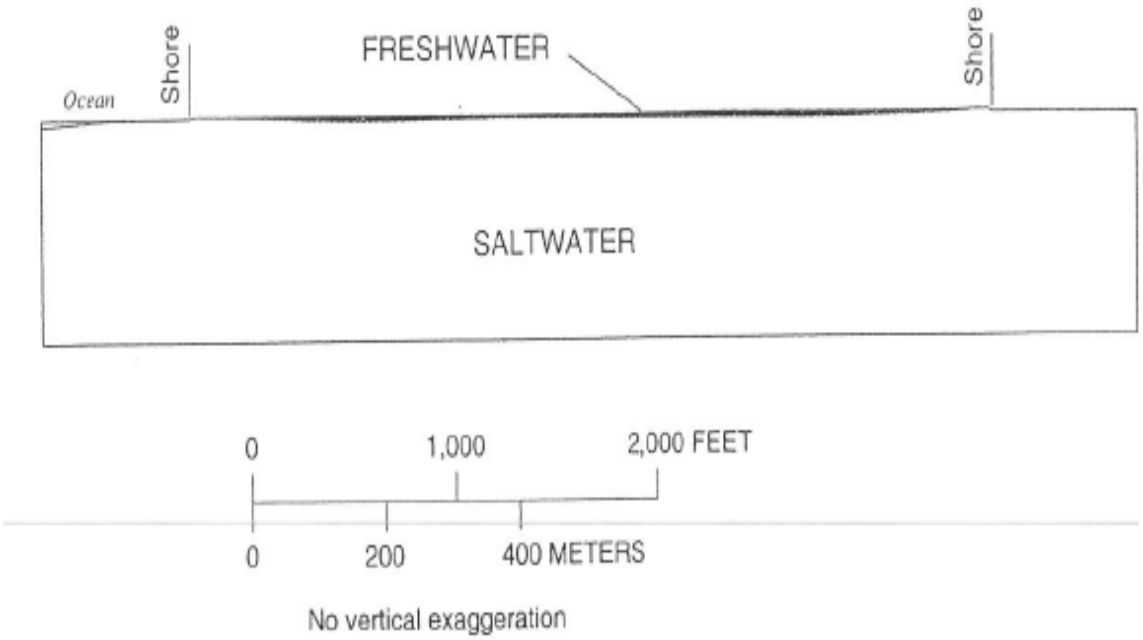


Diagram taken from Reference 3

Tidal Activity

- December 8, 2008 Roi-Namur had high wave activity (onset of dry season)
- Nearly all lenswells were contaminated with salt water
  - -Drinkable chloride concentration= 250 mg/L
  - -Ocean water chloride concentration= 35,000 mg/L
- Only well not contaminated had a history of Volatile Organic Compound (VOC) contamination
- Roughly 12 days of raw water in storage under normal operation
- Roughly 30 days of treated water in storage under normal operation

Situational Assessment

- Utilize contaminated lenswell to supplement drinking water
  - What contaminants and how much?
  - VOC data on records dated 2001
  - Will current water treatment remove suspected VOCs?

2001 Source Water Data For Contaminated Lenswell

Contaminant	Result (ug/L)	EPA Maxium Contaminant Level (MCL) (ug/L)	Potential Long-Term Health Effects	Sources of Contamination
Trichloroethylene (TCE)	5.1	5	Increased risk of cancer	Metal cleaning operations
Tetrachloroethylene or Perchloroethylene (PCE)	16	5	Increased risk of cancer; liver problems	Metal cleaning operations
cis - 1,2 - Dichloroethylene (cis - 1,2 - DCE)	7.2	70	Liver problems	Industrial chemical
trans - 1, 2 - Dichloroethylene (trans - 1,2 -DCE)	1.5	100	Liver problems	Industrial chemical

Extending Water Supply

- Water treatment consisted of Granular Activated Carbon (GAC)

  - Natural Organic Matter competition (Disinfectant By-Product (DBP) Precursors)

  - Treatment not proven for VOC removal

- 20/80 lenswell to rain water mixture recommended

  - PCE value of 3 ug/L (EPA MCL = 5 ug/L)

  - Extended water usage by 3 days under normal operation

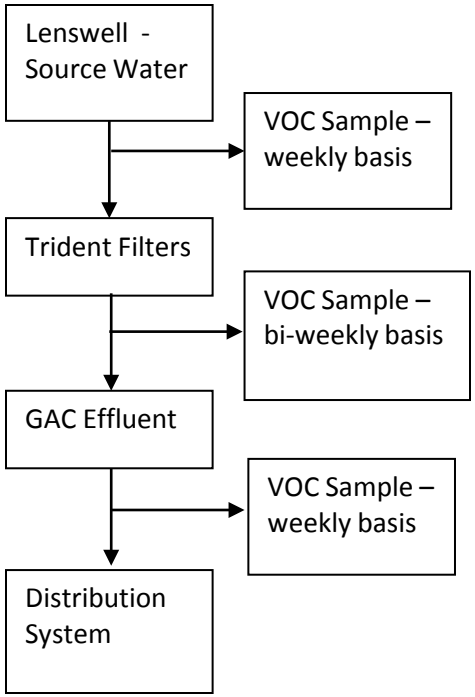
- Expedited VOC sample containers

Monitoring Scheme

- Water monitoring frequency
- Monitoring results

  - No detects after Trident filter or GAC effluent during same time period and frequency

  - Table below shows results from contaminated lenswell (Only detected parameters are listed in Table)



Contaminant (all results in ug/L unless otherwise stated)	EPA MCL	12/17/2008	12/31/2008	1/7/2009	1/19/2009	1/26/2009
trans-1,2-Dichloroethene	100	1	3	2	2	3
cis-1,2-Dichloroethene	70	6	20	9	8	10
Trichloroethene(TCE)	5	3	8	5	5	7
Tetrachloroethene(PCE)	5	9	20	10	10	10

Sustainable Water Supply

- Potential risk to contaminated lenswell
  - Only source of water
  - High drawdown rates could damage well
- Other water options
  - Barge water from Kwajalein Island
  - Dig new wells
  - Install new treatment for brackish water (reverse osmosis purification units (ROWPUs))

Contact Made

- Procedure for obtaining temporary ROWPU
  - Contacted the Program Manager-Petroleum and Water Section (PM-PAWS)
  - Advised to contact Pacific Command (PACOM)
  - Request eventually routed through PACOM
- Temporary ROWPUs installed on Roi-Namur on February 6, 2009
- Efforts for permanent reverse osmosis system

Recovery Time

- ROWPU / Reverse Osmosis costly
- Rain Needed!
- Estimated recovery time = 2 years (2011)
- Permanent Reverse Osmosis System installed January 2010
- Very good lenswell water quality this year

•Estimated Lenswell Volume = 226 X 10^6 gal = 30.2 X 10^6 ft^3 (reference 2)
•Estimate of Lenswell Area = 5.25 X 10^6 ft^2 (reference 2)
•Average Annual Rainfall = 100 inches = 8.33 ft (reference 1)
•Recharge Rate =30 % of average annual rainfall (reference 8)
•Estimate of Annual Recharge = 0.3 x 8.33 = 2.50 ft/yr
•Estimated Time to Remove Saline Water = 30.2/5.25/2.50 = 2.30 years

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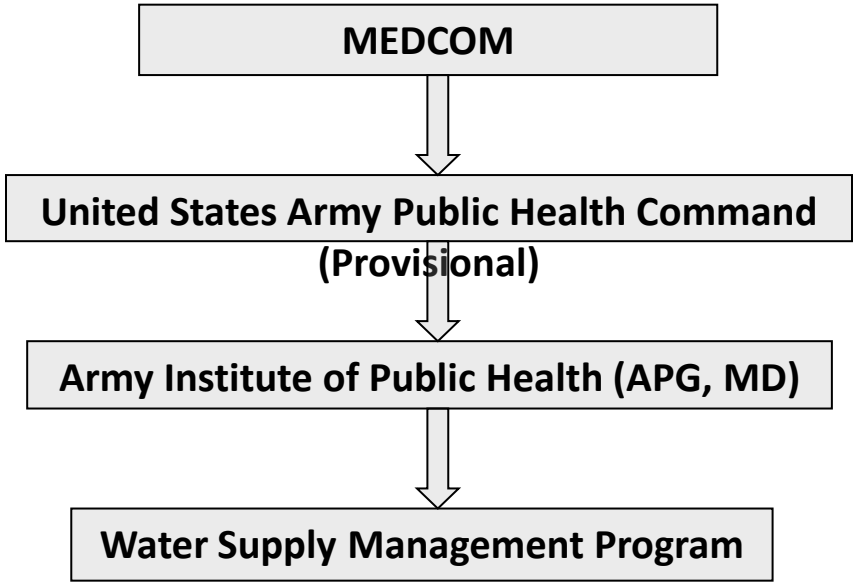
Who Are We?

USAPHC
U.S. ARMY PUBLIC HEALTH COMMAND (Provisional)

- We are the United States Army Public Health Command (Provisional) (USAPHC (Prov)) formally known as the Center for Health Promotion and Preventive Medicine (USACHPPM)
- We provide consultative expertise to Army and DoD installations worldwide for environmental health aspects of drinking water supply, treatment, and distribution, as well as recreational waters.
- We have a multi-disciplined team of engineers, scientists, biologists, and technicians supported by an extensive analytical laboratory



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